ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 18

FILTER EXPERIMENTS

RCA INSTITUTES, INC.
A SERVICE OF RADIO CORPORATION OF AMERICA
HOME STUDY SCHOOL
350 West 4th Street, New York 14, N. Y.

Experiment Lesson 18

OBJECT:

1. To compare three resistor-capacitor *(RC)* filtering circuits for d-c output and ripple voltage.

2. To compare pi-type with choke input *LC* filtering for d-c output and ripple voltages.

3. To compare the half-wave and full-wave rectifiers for d-c output and ripple voltages.

METHOD

In this experiment lesson, you will study three widely-used types of low-pass filter circuits. You will be experimenting with these filters in order to see what advantages one filter circuit has over another. It will be easy to compare the filters, because each one will be fed by the same power transformer and rectifier and will operate into the same two loads. You will want to observe which system has the highest d-c output voltage, which has the best regulation, and which has the least ripple voltage. To determine the effectiveness of each filter, you will perform this experiment on each filter circuit, measuring the d-c and ripple output voltages.

EQUIPMENT NEEDED

Multimeter

Receiver chassis

Soldering iron and solder

390-ohm 1-watt resistor

One 1000-ohm 1-watt resistors

One 5000-ohm 10-watt resistor

One 10,000-ohm 5-watt resistor

One 47,000-ohm 1-watt resistor

One electrolytic filter capacitor:
20 μf 300 volts, 20 μf 300 volts,
40 μf 300 volts, 25 μf 25 volts

Capacitor mounting ring

Capacitor board

Miscellaneous hardware

PREPARATION

In preparation for this lesson, study Theory Lesson 18, which discusses the theory of various basic filtering circuits.

Caution: In this lesson, as in other recent Experiment Lessons, you will be working with voltages that can hurt you if you are not careful. Follow the directions for each experiment just as they are given to you. Do not touch any part of the wired circuit with your bare hands when the a-c line voltage is applied.

METHOD.

In performing experiments, some people prefer to work from a schematic diagram, while others would rather follow step-by-step instructions. For those who wish to work with a schematic diagram, we will provide one for each experiment, where one is called for. Also, for those who would rather work with more detailed instructions, step-by-step wiring instructions will be given. However, even if you work directly from the schematic diagram, you may want to check your work by reading over the step-by-step instructions.

Electrolytic filter capacitors are marked so that the terminals of each unit may be identified. If you examine the capacitor closely, you will find that three of the inner ring of terminal lugs are marked as shown in Fig. 18-1*a*. One is marked with a semicircle, another is marked with a square, and a third is marked with a triangle. The fourth lug is unmarked. If you then look at the label or stampings on the metal can, you will find, as in Fig. 18-1*b*, that it gives the capacity of each capacitor section identified by these markings. In addition, you can see the voltage rating of each capacitor section and the indication that the can is the common negative connection to all sections.

Capacitor manufacturers do not always use exactly the same method of identifying capacitor sections. Therefore, the capacitor that you received in Kit 8 may be marked in a slightly different way than the one that we used in our laboratory tests. For that reason, it is necessary now that you identify each capacitor section of your filter capacitor. Find out which section has a capacity of 40 μf (300 VDC), which sections have a capacity of 25 μf (300 VDC), and which section has a capacity of 20 μf (25 VDC). On a sheet of paper, write the symbol for the 40-μf section of your capacitor. Then on the same line, write: 40 μf #1. If your capacitor is just like the one we used in the lab, the line will look something like this:

⌓ 40 μf #1

On the next line, mark the symbol for the first 20-μf section, followed by its capacity (20 μf) and #2. On the third line, mark the symbol and capacity of the second 20-μf section and call this #3. The 25-μf low-voltage section will not be used in this lesson, so do not bother to mark it down.

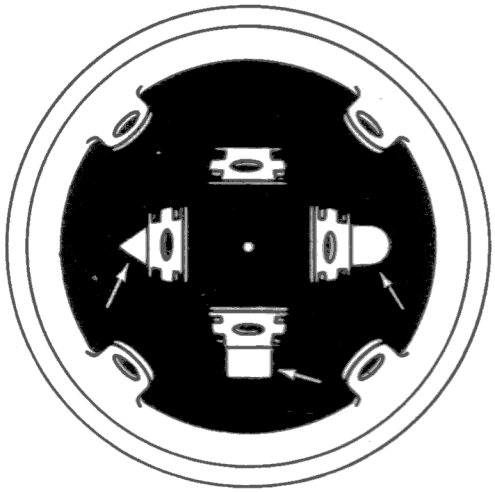
When we were through with our list, it looked like this:

⌓ 40 μf #1

□ 20 μf #2

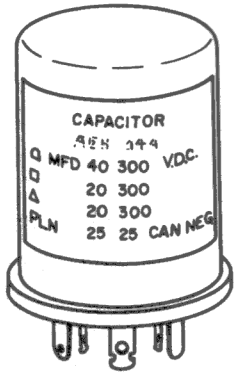
△ 20 μf #3

In the experiments that follow, each section will be identified by the number as given above.



bottom view of capacitor showing lug markings

(a)



(b)

Fig. 18-1

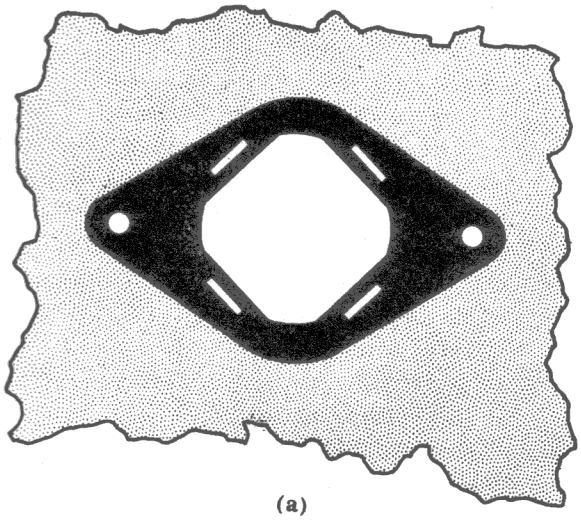
JOB 18-1

To mount the filter capacitor on the receiver chassis.

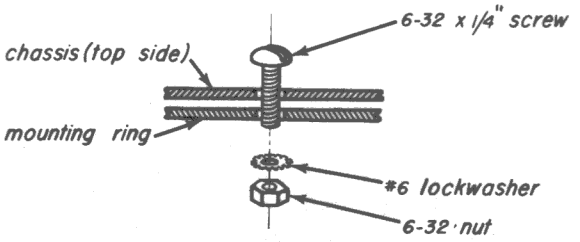
Procedure.

Step 1. Support the chassis upside down on the 2" x 4" wooden blocks.

Step 2. Plact the capacitor mounting ring over the hole shown in Fig. 18-2*a*.



(a)



(b)

Fig. 18-2

Step 3. Fasten the ring to the chassis with two 6-32 x 1/4-inch screws and nuts and two #6 lockwashers, as shown in Fig. 18-2*b*.

Step 4. Turn the chassis right side up on the bench.

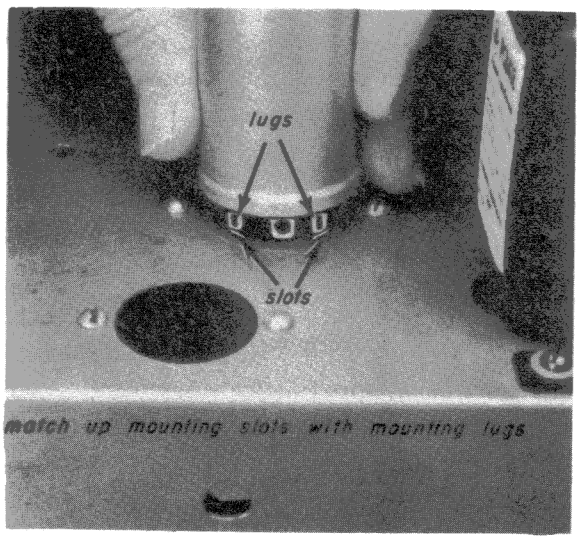


Fig. 18-3

Step 5. Hold the capacitor so that the 20-μf section #2 is facing the rectifier socket, as in Fig. 18-3, and insert the four capacitor mounting lugs in the slots in the mounting ring.

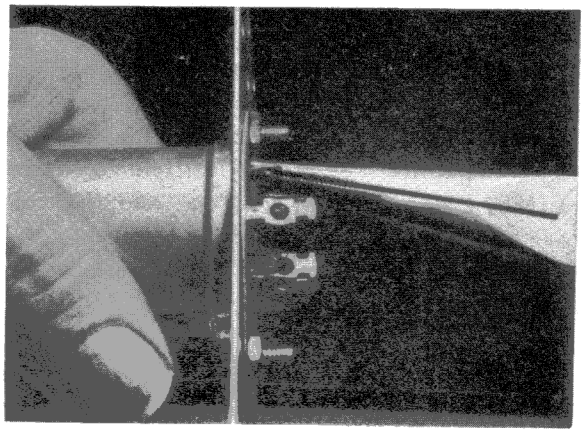


Fig. 18-4

Step 6. In this step, you must hold the capacitor firmly against the capacitor ring, so that the capacitor does not slip out of the ring as you turn the chassis on its end. Then, still holding the can firmly against the mounting ring with one hand, with a pair of pliers held in the other hand, twist each of the mounting lugs, as shown in Fig. 18-4. Be sure that you twist the mounting lugs and not the terminal lugs. Figure 18-5 shows the bottom view of the capacitor that has been properly mounted.

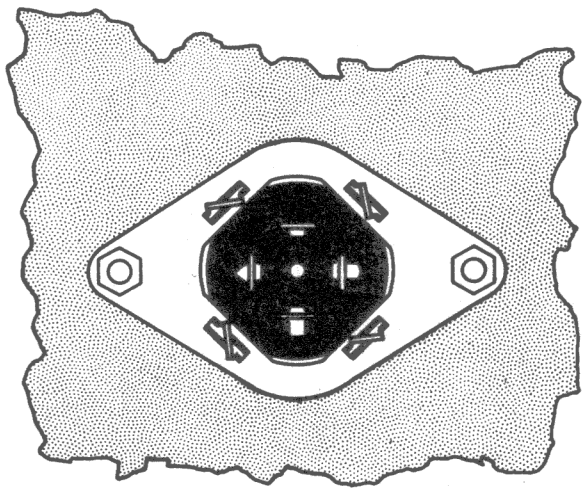


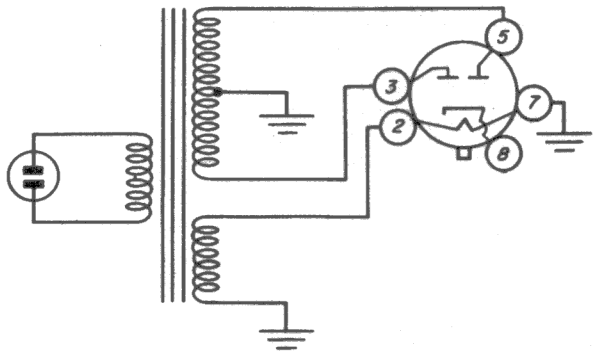
Fig. 18-5

EXPERIMENT 18-1.

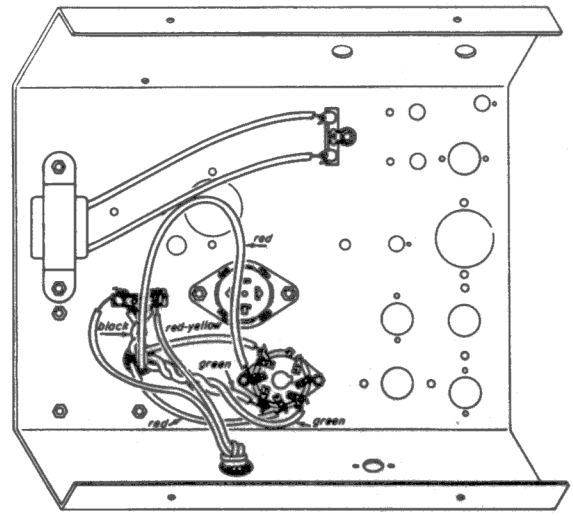
To measure the pulsating d-c voltage of a power supply that has no filter.

Method. In the experiments that follow, you will wire several widely used types of filter circuits and connect each of them to a power-transformer rectifier circuit. The output of a rectifier circuit is a pulsating d.c., which, as you know, is a voltage that varies in value between zero and maximum – with each pulse always in the same direction. The object of the filter is to change this varying d-c voltage into an unchanging d.c. In this experiment, you will examine the pulsating d.c. before filtering so that you can compare the effectiveness of each filtering system. You will do this by measuring the output of the rectifier (across the load resistor) with the d-c section and the output section of your multimeter. Later, when you apply filters to the rectifier output, you will find that it is necessary to block the d-c component of the voltages that you measure in order to find out how much the a-c component is.

To use the output section of your multimeter, take the red lead out of the red jack and place it in the yellow (OUTPUT) jack. (The black lead remains in the black jack.) The capacitor that you wired from the yellow jack to the red jack is connected in series with the a-c voltmeter circuit and blocks any d.c. that may be in the circuit under test, which permits only the a.c. to reach the meter. When making a-c measurements with the output meter, you will find that the pointer moves up scale rapidly, due to the charging of the blocking capacitor, and then falls back to the value of voltage being measured. This condition is normal and does not harm your meter. Always use the OUTPUT jack when you wish to measure the a-c component of any circuit that contains both a.c. and d.c. Do not use the output jack to measure a.c., when no d.c. is present, such as a-c line or heater voltages. The reason for this is because of the reactance of the blocking capacitor, the voltage that reaches the a.c voltmeter is reduced.



(a)



(b)

Fig. 18-6

Figure 18-6*a* and *b* show a schematic and a wiring diagram of the connections that you made for the last experiment of Experiment Lesson 17. If you have made any changes in the wiring, it will be necessary for you to return the wiring to the condition shown in the drawings.

Procedure.

Step 1. Check the wiring on the receiver chassis. If it is correct, go on to the next step.

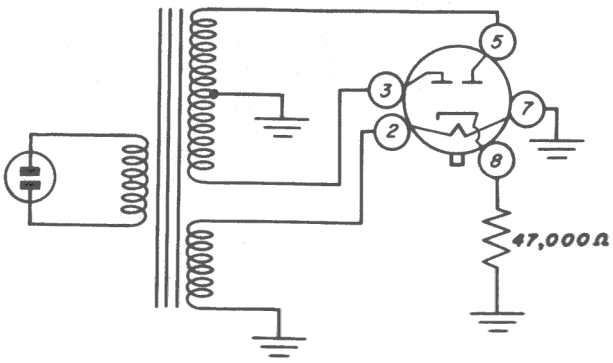
Step 2. Temporarily solder one end of the 47,000-ohm resistor to pin 8 and the other end to a ground lug, as shown in the schematic of Fig. 18-7*a* and the wiring diagram of 18-7*b*.

Step 3. Plug the line cord in the a-c outlet.

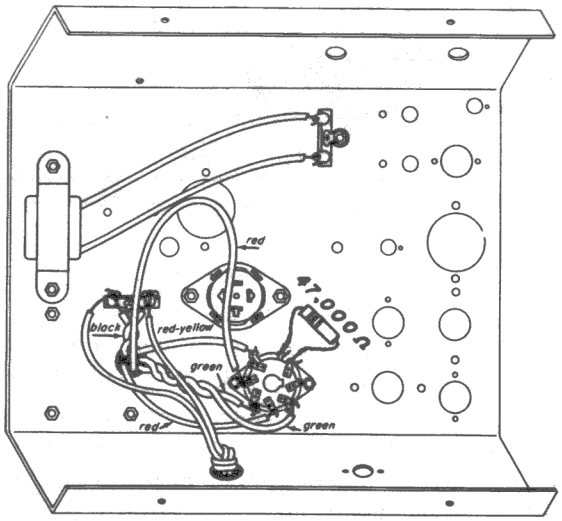
Step 4. Set the multimeter for service as a d-c voltmeter on the 500 VDC range, and measure the voltage between terminal 8 of

the tube socket and ground. Record the voltage here:

~~280~~ 220
volts d.c. output



(a)



(b)

Fig. 18-7

Step 5. Set the multimeter for operation as an OUTPUT meter. Turn the function switch to the AC position and the range switch to the 300 VAC position, and place the red lead in the yellow jack. Measure the a-c ripple voltage across the 47,000-ohm load resistor. Record the reading here:

106
volts a.c. output

Step 6. Remove the line cord from the a-c outlet.

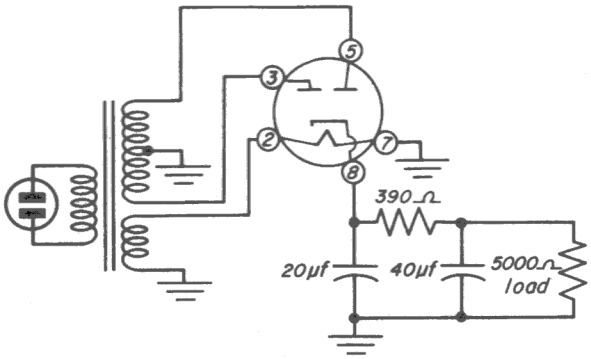
Step 7. Remove the 47,000-ohm resistor.

EXPERIMENT 18-2

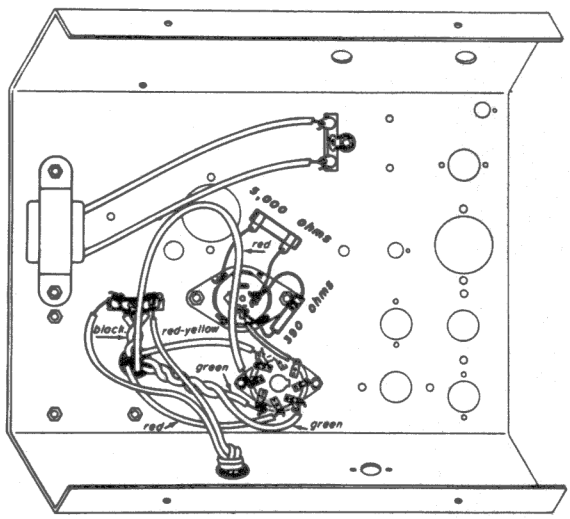
To study low-pass, pi-type resistor-capacitor filter circuits.

capacitor input filter

Method. In this experiment, you will connect a pi-type *RC* filter to the power-transformer rectifier circuit, as shown in the schematic diagram in Fig. 18-8*a*. Figure



(a)



(b)

Fig. 18-8

18-8*b* shows what the wiring should look like. You will use three values of resistance in the resistor part of the *RC* filter. The first of these, the 390-ohm resistor, was selected because its d-c resistance almost equals the resistance of the filter choke that

you will use later as a permanent part of your receiver. Two other values were chosen because they are typical of those used in such filter circuits. You will measure and record the d-c output and ripple voltages for each of these filters, when the output of the filter is fed to a 5,000-ohm load and when it is fed to a 10,000-ohm load. Thus, you can compare one filter with another, and, later, compare these filters with other filters.

Procedure.

Step 1. With a piece of hookup wire, solder one end permanently to terminal 8 of the tube socket. (Use the lower hole, because another wire will be inserted later.) *Connect* the other end temporarily to the 20-μf capacitor, #2.

Step 2. Solder one lead of the 390-ohm resistor temporarily to the same 20-μf capacitor and *connect* the other end temporarily to the 40-μf capacitor, #1.

Step 3. Solder one lead of the 5,000-ohm resistor temporarily to the 40-μf capacitor, #1, and the other end temporarily to ground. Make sure that the leads do not touch any other capacitor lugs or short to the can.

Step 4. Check your wiring carefully and then plug the line cord into the a-c outlet.

Step 5. With your multimeter set up for service on the 500 VDC range, measure the voltage at the input to the filter (between terminal 8 of the tube socket and ground). Record the voltage here:

~~300~~ 260
volts d.c. input

Step 6. Measure the d-c voltage (at the output of the filter at the 40-μf section, #1, and ground). Record the voltage here:

240
volts d.c. output

Step 7. With your multimeter, set up as an OUTPUT meter for operation on the 15 VAC range and the red lead in the OUTPUT (yellow) jack, measure the ripple voltage at the input and at the output to the filter. Record the voltages here:

1.5
volts a.c. input

.2
volts a.c. output

Step 8. Disconnect the line cord from the a-c outlet.

Step 9. Substitute the 10,000-ohm load resistor for the 5,000-ohm resistor that is now between the terminal of 40-μf capacitor, #1, and ground.

Step 10. Check your wiring to make sure that you didn't drop any solder near the capacitor or the tube terminals. Then plug the line cord into the a-c line.

Step 11. Measure the d-c voltage at the input and the output of the filter (as you did in Step 7). Record them here:

~~360~~ 282
volts d.c. input

~~340~~ 272
volts d.c. output

Step 12. Measure the a-c ripple at the input and at the output of the filter and record it here:

1.0
volts a.c. input

0.1
volts a.c. output

Step 13. Disconnect the line cord from the a-c outlet. Unsolder the 390-ohm resistor from the terminals #2 and #1 of the capacitor.

Step 14. Solder one 1,000-ohm 5-watt resistor between the same capacitor terminals.

Step 15. Plug the line cord into the a-c outlet. Using the proper d-c range, measure

the d-c voltage at the input and at the output of the filter. Record them here:

288.0 volts d.c. input	~~300~~ 260 volts d.c. output

Step 16. Using the OUTPUT meter, measure and record the input and output ripple voltage. Record the voltages here:

0.8 volts a.c. input	0.1 volts a.c. output

Step 17. Disconnect the line cord from the a-c outlet.

Step 18. Substitute the 5,000-ohm resistor for the 10,000-ohm resistor in the load.

Step 19. Plug the line cord into the a-c outlet.

Step 20. Measure the d-c voltage at the input and at the output of the filter. Record them here:

~~220~~ 270 volts d.c. input	~~CANCELED~~ 220 volts d.c. output

Step 21. Using the OUTPUT jack, measure the ripple voltages at the input and output of the filter. Record them here:

0 volts a.c. input	0 volts a.c. output

Step 22. Disconnect the line cord from the a-c outlet.

Step 23. Unsolder one end of the 1,000-ohm filter resistor and solder in its place one end of the second 1,000-ohm resistor. Solder the free ends of these resistors together, as shown in Fig. 18-9. If this is wired properly, you now have 2,000 ohms of resistance in the *RC* filter, which feeds into a 5,000-ohm load.

Step 24. Plug the line cord into the a-c outlet.

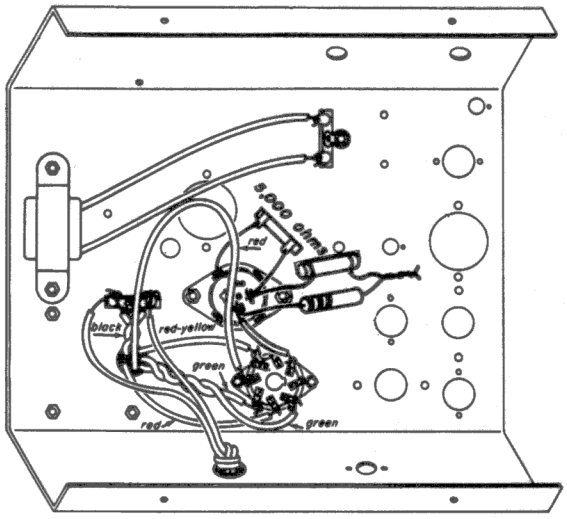


Fig. 18-9

Step 25. Measure the d-c voltages at the input and the output of the filter and record them here:

273.0 volts d.c. input	192 volts d.c. output

Step 26. Use the OUTPUT meter to measure the ripple voltages at the input and output of the filter and record them here:

1.2 volts a.c. input	0.1 volts a.c. output

Step 27. Disconnect the line cord from the a-c outlet.

Step 28. Substitute the 10,000-ohm load resistor for the 5,000-ohm load in use.

Step 29. Plug the line cord into the a-c outlet.

Step 30. Measure the d-c voltage at the input and at the output of the filter. Record them here:

285 volts d.c. input	238 volts d.c. output

Step 31. Using the OUTPUT meter, measure the ripple voltages at the input and the output of the filter. Record them here:

0,8 volts a.c. input	0,1 volts a.c. output

Step 32. Disconnect the line cord from the a-c outlet.

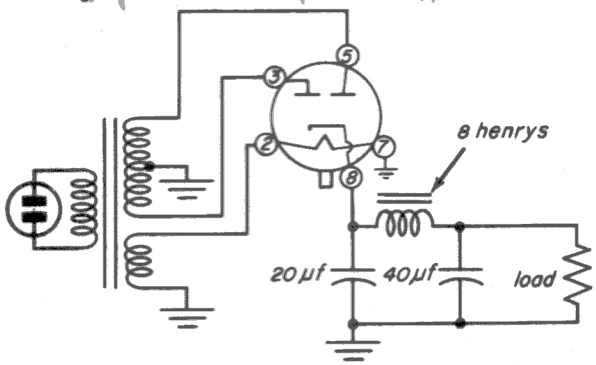
Step 33. Unsolder and remove the two 1000-ohm resistors from capacitor terminals #1 and #2.

EXPERIMENT 18-3

To compare pi-type *LC* filtering with choke input filtering.

Method. In this experiment, you will hook up a pi-type *LC* filter, using the 20-μf and 40-μf sections of the capacitor with an 8-henry choke. You will measure the d-c and ripple voltages at the input and output of the filters, under 5,000-ohm and 10,000-ohm load. You will then compare the pi-type filtering with choke input filtering with the same loads.

capacitor input filter



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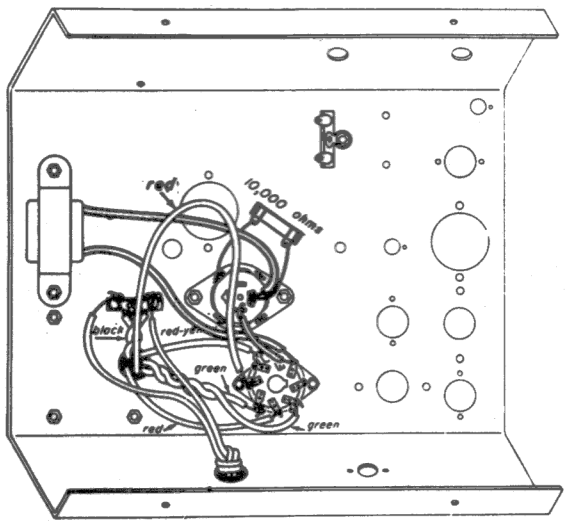
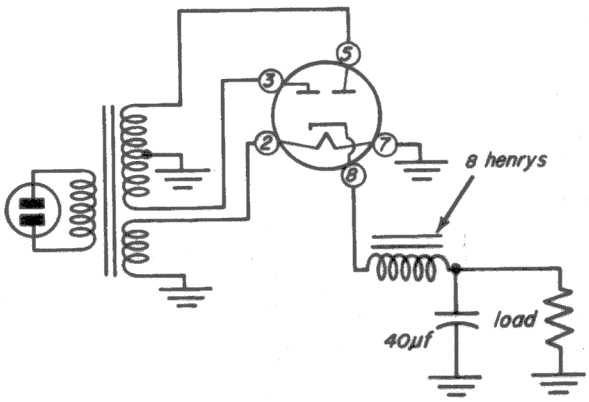


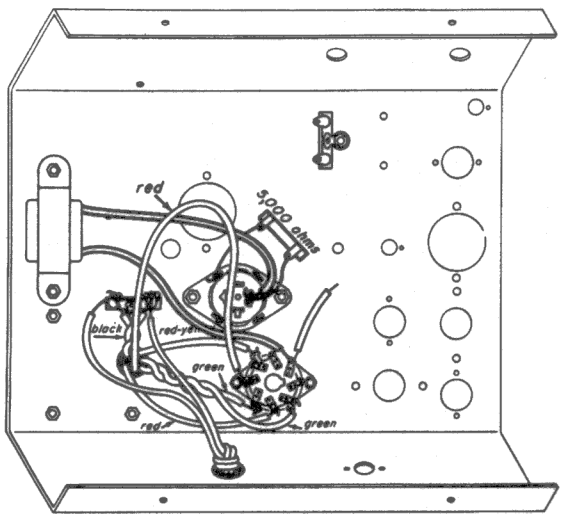
(b)

Fig. 18-10

Figure 18-10*a* shows the schematic diagram of the power supply with a pi-type *LC* filter, and Fig. 18-10*b* shows the wiring diagram. Figure 18-11*a* shows the schematic diagram of the power supply with a choke-input type filter, and Fig. 18-11*b* shows the wiring diagram.



(a)



(b)

Fig. 18-11

Procedure.

Step 1. Unsolder the choke terminals from the terminal strip to which they have been connected during recent lessons.

Step 2. Cut, dress, and solder one choke lead permanently to terminal 8 of the tube

socket and solder the other temporarily to the 40-μf capacitor, #1.

Step 3. Check your circuit and make sure that it is correct; as shown in Fig. 18-10; then plug the line cord into the a-c outlet.

Step 4. With your meter on the 500 VDC range, measure the d-c voltage across the input and the output of the filter circuit. Record them here:

285 volts d.c. input

273 volts d.c. output

Step 5. Measure the input and output ripple voltages, and record them here:

1.0 volts a.c. input

0.1 volts a.c. output

Step 6. Disconnect the line cord from the a-c outlet.

Step 7. Substitute the 5,000-ohm load resistor for the 10,000-ohm load resistor that is now between the filter output and ground.

Step 8. Place the line cord in the a-c outlet.

Step 9. Change the meter to 500 VDC operation and measure the input and output d-c voltages. Record them here:

261 volts d.c. input

240 volts d.c. output

Step 10. Set your meter as an OUTPUT meter and measure the input and output ripple voltages. Record them here:

1.4 volts a.c. input

0.1 volts a.c. output

Step 11. Disconnect the line cord from the a-c outlet.

Step 12. At the input 20-μf capacitor, #2, unsolder the lead that connects it to terminal 8 of the tube socket. Do not unsolder the other end of the lead. Move the free end so that it is not making contact with anything. Check your wiring against Fig. 18-11.

Step 13. Plug the line cord into the a-c outlet and measure the d-c voltages at the filter and record them here:

200 volts d.c. input

181 volts d.c. output

Caution: Before you measure the ripple voltages, change to the 300 VAC range of the multimeter. Using any lower range in measuring ripple voltage in Steps 14 and 18 will seriously overload the meter. For the output-ripple reading, the lowest a-c range can be used.

Step 14. Measure the ripple voltages, as before. It is necessary to use the 300 VAC range for the input ripple. Record the voltages here:

106 volts a.c. input

0.1 volts a.c. output

Step 15. Disconnect the line cord from the a-c outlet.

Step 16. Remove the 5,000-ohm load resistor and replace it with the 10,000-ohm load resistor.

Step 17. Plug the line cord into the a-c outlet and measure the d-c voltages and record them here:

210 volts d.c. input

200 volts d.c. output

Step 18. Measure the input ripple voltage on the 300 VAC scale and output ripple on

the 15 VAC scale and record them here:

106	0.1
volts a.c. input	volts a.c. output

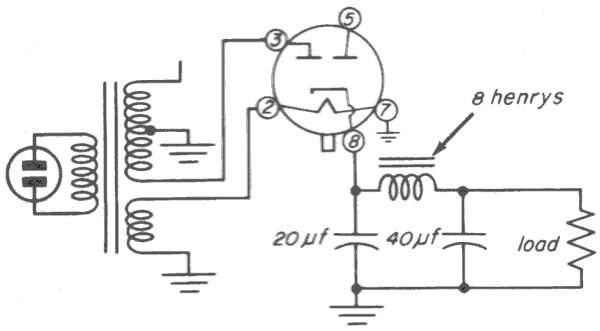
Step 19. Disconnect the line cord from the a-c outlet.

Step 20. Solder the free end of the lead connected to socket terminal 8 permanently to the 20-μf capacitor, *2. Dress the wire neatly.

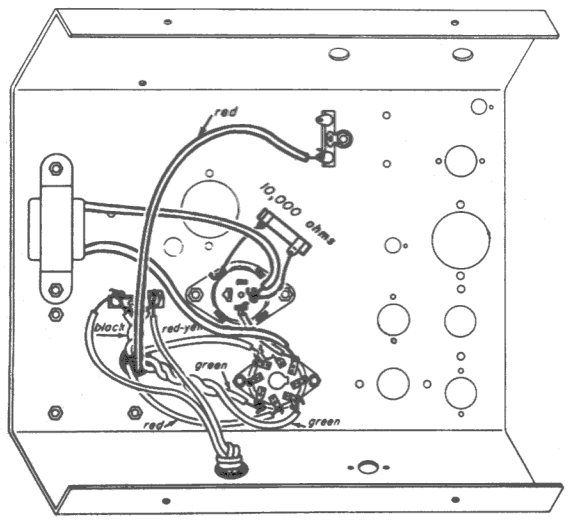
EXPERIMENT 18-4

To study the d-c output and ripple voltages of a filtered half-wave rectifier.

Method. The information that you will receive in this experiment will enable you to compare all of the filters that we spoke of earlier in the lesson. You will wire the half-wave rectifier circuit shown in Fig. 18-12*a* and take d-c and ripple measurements in the same way that you did in the first two experiments.



(a)



(b)

Fig. 18-12

Procedure.

Step 1. Remove the lead that connects lug 5 of the tube socket with one of the red leads of the transformer high-voltage. Solder it temporarily to a free lug on the terminal strip that you removed the choke leads from earlier in this lesson.

Step 2. Check your wiring with the diagram in Fig. 18-12*b*. If it is correct, plug the line cord into the a-c outlet.

Step 3. Switch your meter over for operation on the 500 VDC range and measure the d-c voltages. Record them here:

253	242
volts d.c. input	volts d.c. output

Step 4. With an OUTPUT meter on the 15 VAC range, measure the input and output ripple voltages. Record them here;

1.1	0.1
volts a.c. input	volts a.c. output

Step 5. Disconnect the line cord from the a-c outlet.

Step 6. Replace the 10,000-ohm load resistor with the 5,000-ohm load resistor.

Step 7. Measure the d-c voltages and record them here:

224	205
volts d.c. input	volts d.c. output

Step 8. Measure the ripple voltages and record them here:

1.7	0.1
volts a.c. input	volts a.c. output

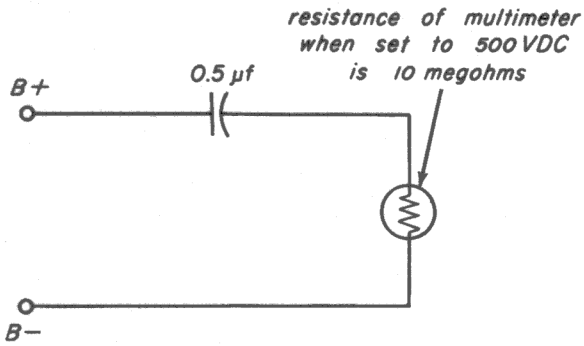


Fig. 18-13

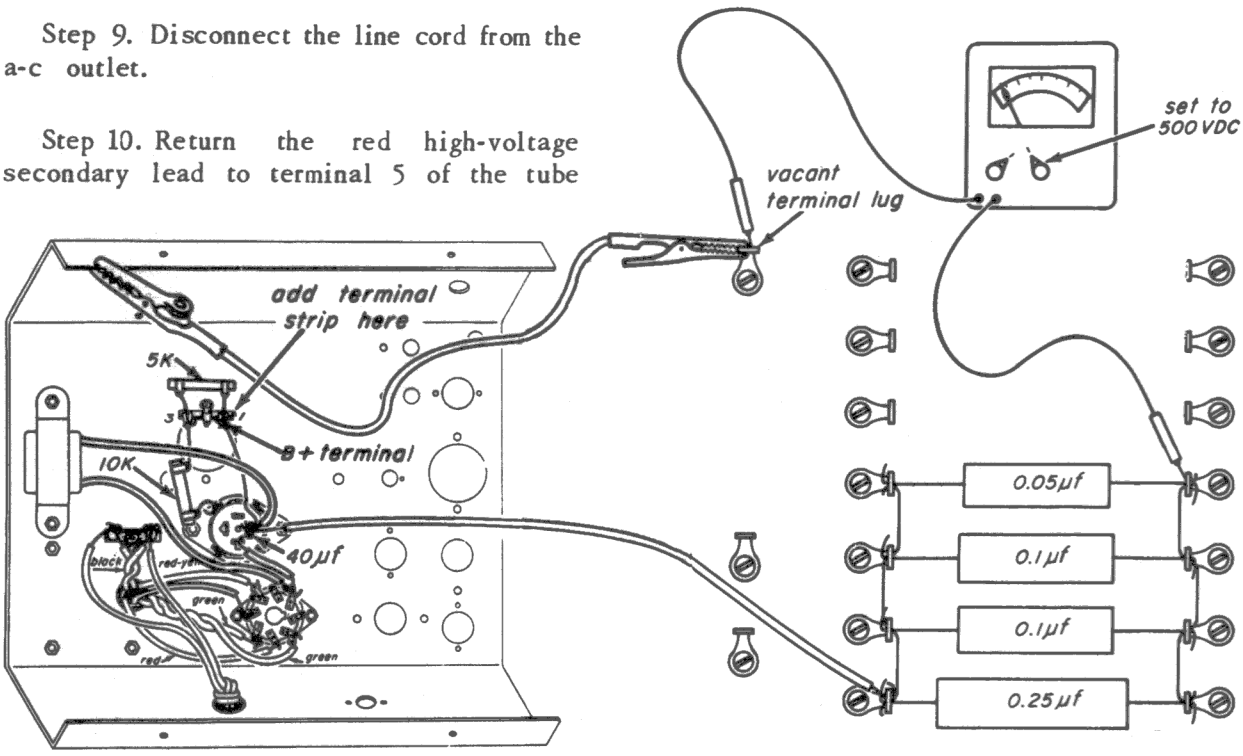
Step 9. Disconnect the line cord from the a-c outlet.

Step 10. Return the red high-voltage secondary lead to terminal 5 of the tube socket. This is a permanent connection, so cut, dress, and solder the lead accordingly.

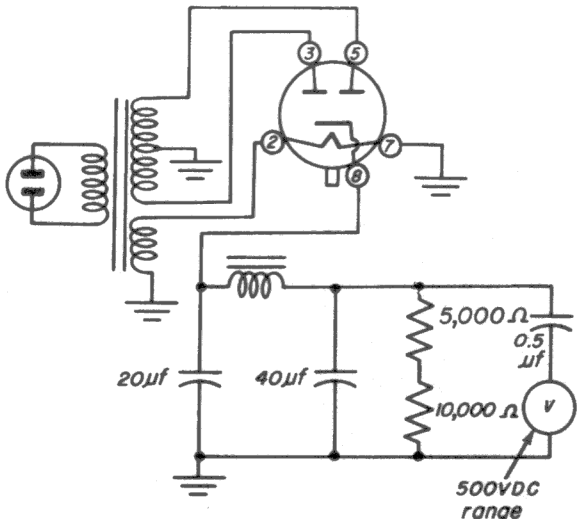
EXPERIMENT 18-5

To study the manner in which a capacitor charges and discharges through a resistor.

Information. In this experiment you will set up an *RC* circuit with a time constant long enough so that you can follow on your meter the manner in which the capacitor charges and discharges. To study the charging of a capacitor, you will experiment on a circuit similar to that shown in Fig. 18-13. The applied voltage will be obtained from the receiver power supply. The *RC* circuit consists of a 0.5-μf capacitor in series with your multimeter set on the 500 VDC range. The total resistance of the voltmeter is 10 megohms. The meter will serve two useful purposes: as a resistor and as a voltmeter. To study the discharging of the capacitor, you will place the meter across the charged capacitor. By taking measurements of the voltage across the series resistor, you will be able to plot curves of the rise of voltage



(a)



(b)

Fig. 18-14

across the capacitor and the fall of voltages across the resistor, and verify what you have learned in the theory lesson regarding *RC* time constants.

Follow the instructions carefully!

Procedure.

Step 1. Mount a terminal strip on the receiver chassis as shown in Fig. 18-14.

Step 2. Disconnect the 5,000-ohm 10-watt resistor and connect it across lugs 1 and 3 on the terminal strip mounted in Step 1.

Step 3. Connect the 10,000-ohm 5-watt resistor from lug 3 on the terminal strip to a ground lug on the electrolytic capacitor. Connect a short piece of wire from lug 1 of this terminal strip to the 40-μf terminal of the electrolytic capacitor. The receiver chassis should now look like Fig. 18-14. The two resistors that you have just connected into the circuit are used as a bleeder and voltage divider across the $B+$ output of the power supply.

Step 4. Connect in parallel the following capacitors on the capacitor breadboard: 0.25 μf, 0.1 μf, 0.1 μf, and 0.05 μf, making a total capacitance of 0.5 μf.

Step 5. Connect a wire from the 40-μf terminal of the electrolytic capacitor to one terminal of the capacitor combination on the breadboard, its shown in Fig. 18-14*a*.

Step 6. Using your clip lead, connect one alligator clip to any convenient ground point on the receiver chassis, and the other clip to a blank soldering lug on the capacitor breadboard.

Step 7. Connect the common multimeter lead to this soldering lug (on the capacitor breadboard) and the positive multimeter lead to the other terminal of the capacitor combination. Set up the meter to the 500 VDC range. Check your circuit against Fig. 18-14. You should now have a series circuit consisting of the meter in series with the 0.5-μf capacitor across the $B+$ output of the power

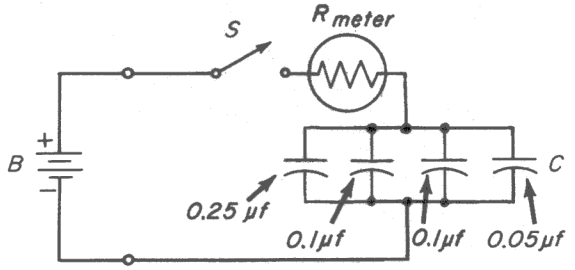


Fig. 18-15

supply, as shown in the schematic of Fig. 18-15.

Step 8. Plug in the a-c cord of the radio chassis and allow the rectifier tube to warm up.

Step 9. Obtain a watch or clock with a sweep second hand. If possible, get someone to help you by counting the seconds out loud for you.

Step 10. Using a long screwdriver that has a well-insulated handle, short out the capacitors on the breadboard. The meter should read the full $B+$ output of the power supply, about 250 volts. Record the voltage in the $t = O$ space of Table *A*. Hold the screwdriver as shown in Fig. 18-16.

Step 11. Remove the short across the capacitors. The capacitors will begin to charge. Read the voltage indicated by the meter *one second after the short has been removed.* Record the voltage in the $t = 1$ space in Table *A*.

Step 12. Place a short across the capacitors to discharge them. Remove the short and read the voltage indicated by the meter two seconds after the short is removed.

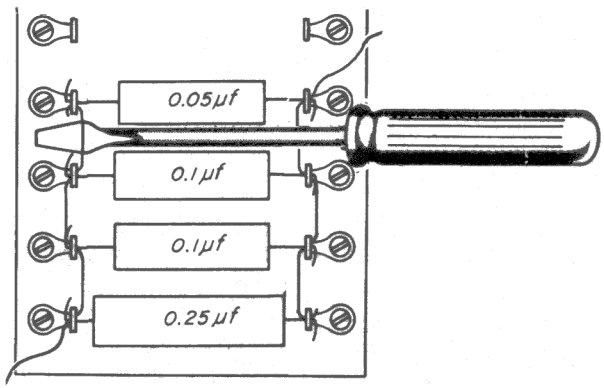


Fig. 18-16

TABLE A		
t (sec)	E_R	E_C
0	290	0
1	250	40
2	220	70
3	200	90
4	185	105
5	160	130
6	140	150
7	130	160
8	110	180
9	100	190
10	90	200
12	60	230
14	45	245
16	32	258
18	25	265
20	18	272
22	14	276
24	13	277
26	10	280

Step 13. Continue as in Step 12 until a voltage reading is obtained for each interval listed in Table *A*.

Note: In Steps 14 through 17, you will study the discharge of the 0.5-μf capacitor into the multimeter. Follow the instructions carefully.

Step 14. Remove the short across the capacitors and allow enough time (30 seconds) for the capacitors to become fully charged.

Step 15. Keeping one hand in your pocket, carefully disconnect the clip lead from the chassis, and lay it aside so that it does not come into contact with any other part of the circuit. Remove the a-c line cord of the radio chassis from the power source.

Step 16. Carefully reverse the meter leads; that is, connect the positive lead to the terminal to which the negative lead was connected. Be careful not to touch any other part of the circuit with the meter leads.

Step 17. Now connect the clip lead to the terminal of the capacitors on the breadboard that is connected to the electrolytic filter capacitor. The meter is now connected across the charged capacitor on the breadboard. The capacitor will now discharge through the resistance of the meter. Observe the meter, and read the voltages indicated by the meter at 5 seconds, 10 seconds, 15 seconds, 20 seconds, and 25 seconds. Record them in Table *B*. How do these voltages compare with the readings obtained in Step 13 for the same amounts of time?

Step 18. Reverse the meter leads again, so that the connections are returned to their original condition, as in Step 7, or Fig. 18-15.

Step 19. The voltage across the capacitors cannot be accurately measured with the equipment available. To obtain the voltage across the capacitor for each instant of time, subtract the voltage across the resistor at that instant from the maximum voltage measured in Step 10. Fill out the third column of Table *A* in this way. The voltage across the capacitor at $t = 0$ is the maximum voltage as measured in Step 10.

Step 20. Plot a curve of the voltage rise across the capacitor and the fall of voltage across the resistor against time on the graph paper provided on the page after the last page of this lesson.

TABLE B	
t (sec)	E_R
5	135
10	60
15	30
20	18
26	8

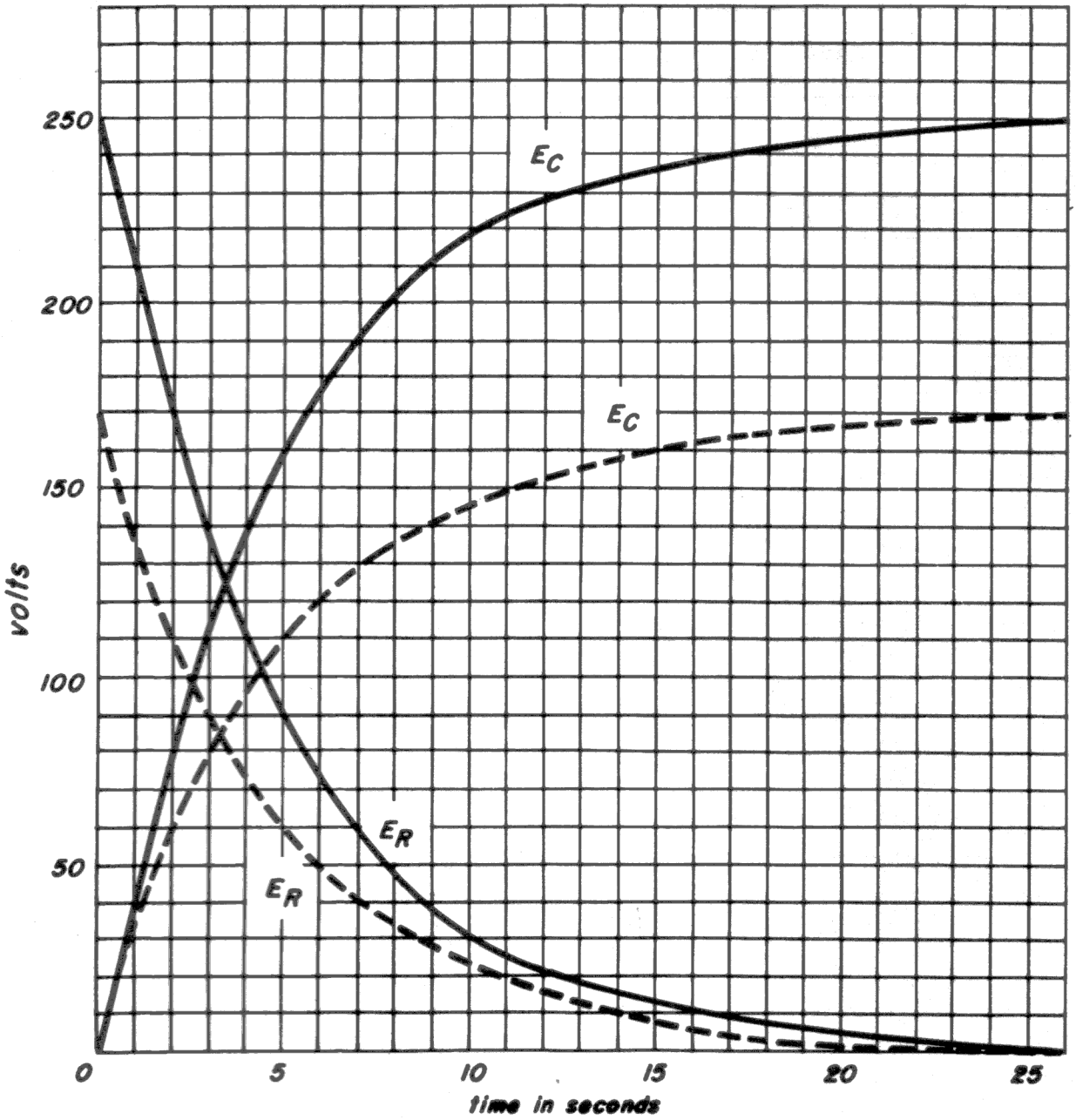


Fig. 18-17

through the plotted points.

EXPERIMENT 18-6

To study the effect of voltages of another value on the charge and discharge of a capacitor through a resistor.

Procedure.

Step 1. Remove the lead from the 40-μf terminal of the filter capacitor on the radio chassis and connect it to the junction of the 5,000-ohm resistor and the 10,000-ohm resistor on the chassis. The $B+$ output at this point is about 170 volts.

Step 2. Repeat Steps 10 to 13 and Step 19 of the previous experiment. Record the results in Table *C* below. Then plot the curve of your results on the same piece of graph paper that you used for Step 20 of Experiment 18-5.

Discussion. These experiments show the way in which a capacitor charges and dis-

TABLE C		
t (sec)	E_R	E_C
0	190	0
1	170	20
2	150	40
3	140	50
4	125	65
5	110	80
6	100	90
7	85	105
8	75	115
9	62	128
10	58	132
12	42	148
14	30	160
16	25	165
18	20	170
20	16	174
22	13	177
24	10	180
26	8	182

charges through a resistor. Removing the screwdriver short across the capacitors is similar to closing the switch *S* in the circuit shown in Fig. 18-15. Tables *D* and *E* show typical results for this experiment, based on *B+* voltages of 250 volts and 170 volts, and Fig. 18-17 shows the curves plotted from these tables. Your plotted curves should be very similar.

The rate at which a capacitor charges and discharges is determined by the *RC* time constant of the combination, which is the product of the resistance in ohms and the capacitance in farads. The meter is used as the series resistor, and its resistance on the 500-volt range is 10 megohms (500 x 20,000). Since the capacitance is 0.5 μf, the time constant is $0.5 \times 10^{-6} \times 10 \times 10^{6} = 5$ seconds.

TABLE D		
t (sec)	E_R	E_C
0	250	0
1	205	45
2	170	80
3	140	110
4	110	140
5	90	160
6	75	175
7	60	190
8	50	200
9	40	210
10	35	215
12	22	228
14	17	233
16	12	238
18	8	242
20	6	244
22	4	246
24	2.5	247.5
26	0	250

As your curves and data should show, in this period of time the capacitor voltage rises to 63% of the maximum value and the resistor voltage falls to 37% of the maximum value. In 5 *RC* periods, or 25 seconds, the capacitor becomes fully charged, and the voltage across the resistor (meter) falls to zero, showing that the current has stopped flowing in the circuit. When the applied voltage is removed and the resistance (meter) is connected across the fully charged capacitor, as in Step 17, the discharge of the capacitor takes place at exactly the same rate as the charge. This is because the resistance in the charging circuit is the same as the resistance in the discharge circuit. However, in many circuits the resistance of the charg-

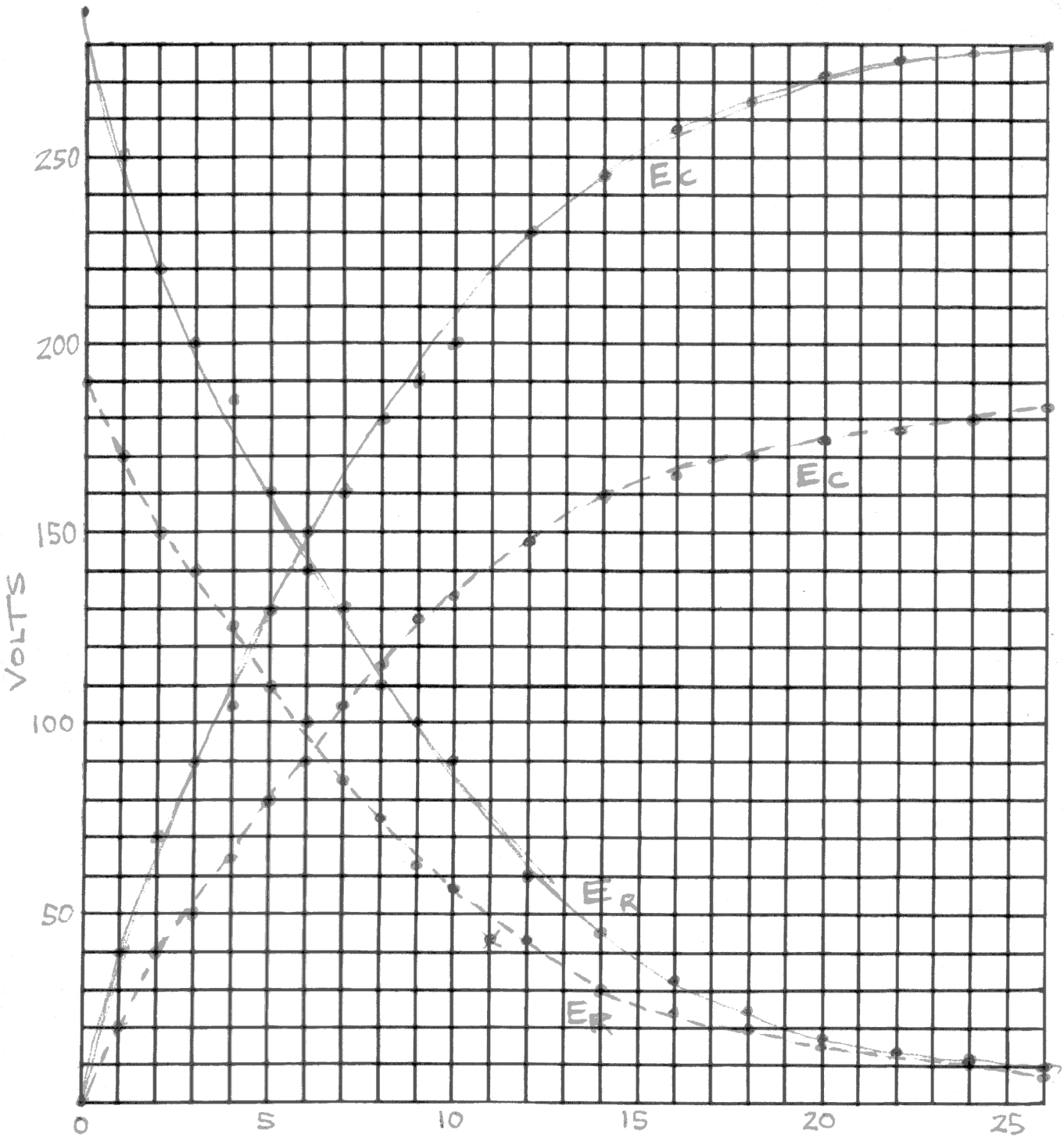
TABLE E		
t (sec)	E_R	E_C
0	170	0
1	140	30
2	110	60
3	90	80
4	75	95
5	60	110
6	50	120
7	40	130
8	35	135
9	30	140
10	25	145
12	15	155
14	10	160
16	8	162
18	6	164
20	4	166
22	2	168
24	1	169
26	0	170

ing circuit is different from the resistance in the discharging circuit. Applications of such circuits will be described in later lessons.

The meter must be reversed in Step 16 because the direction of current flow through the resistor reverses. The current flow through the resistor on discharge is opposite to the direction of current flow during charging.

Your curves should also show that the capacitor becomes fully charged and fully discharged regardless of the maximum value of the applied voltage in RC periods. In each period of RC seconds, the capacitor charges to 63% of the difference between the voltage it is charged to and the maximum voltage. Upon discharge, in each period of RC seconds, the capacitor discharges 63% of the voltage remaining on the capacitor.

With higher applied voltage during charge the voltage across the capacitor rises more rapidly so it becomes fully charged in the same amount of time. Also, when charged up to a higher voltage, the voltage across the capacitor falls more rapidly so as to become fully discharged in the same amount of time.



CUT OUT THIS GRAPH AND USE IT TO PLOT THE DATA IN EXPERIMENTS 18-5 AND 18-6.